

MINERvA CCQE Analysis: First Results

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DNP 2011 Fall Meeting

On behalf of the MINERvA
Collaboration

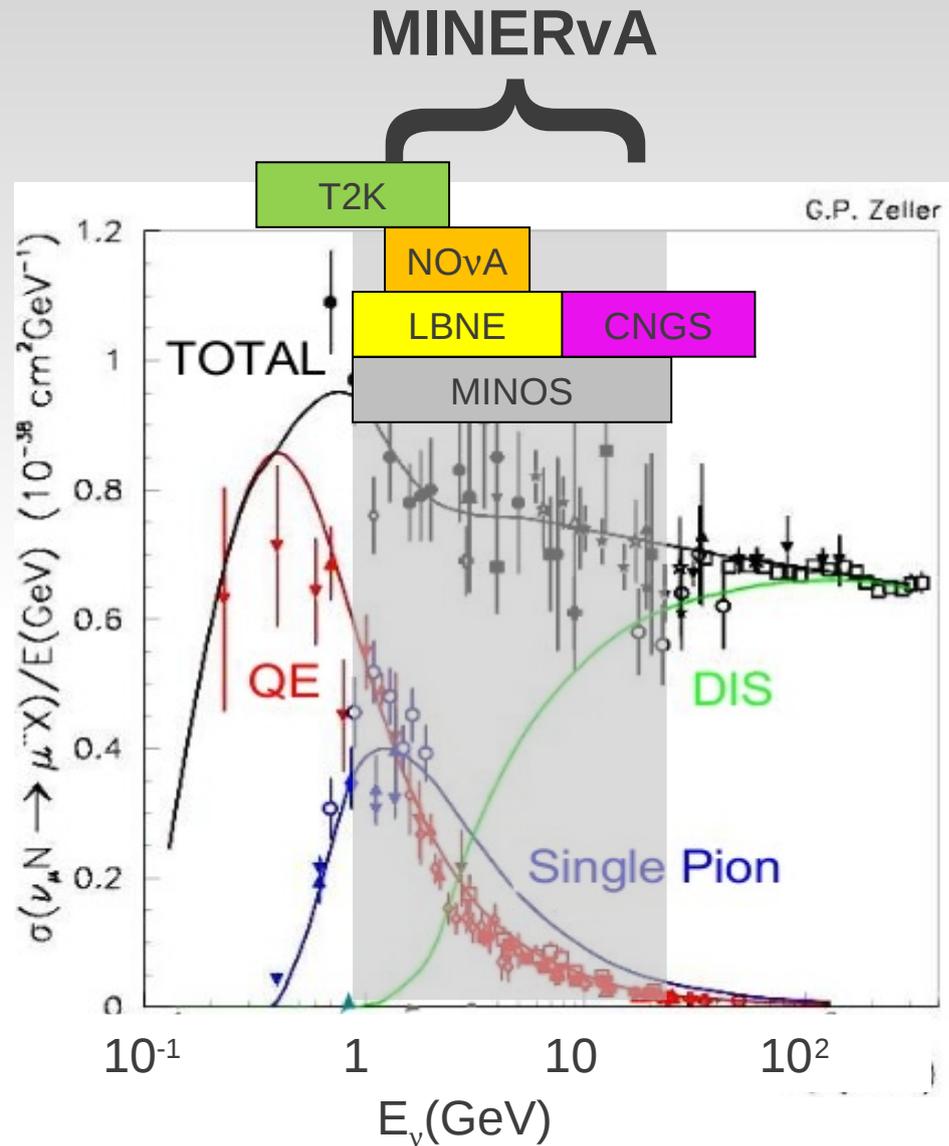
Outline

- Motivation
- NuMI Beamline
- MINERvA Detector
- CCQE Analysis
- Distributions
- Summary



MINERvA: Motivation

- Multiple oscillation experiments in O(GeV) neutrino beams
 - CCQE
 - Resonant Pion Production
 - DIS
- Precision oscillation measurements require precision cross-section measurements
- Understand oscillation backgrounds
 - $\nu_{\mu} \rightarrow \nu_e : \pi^0$ production

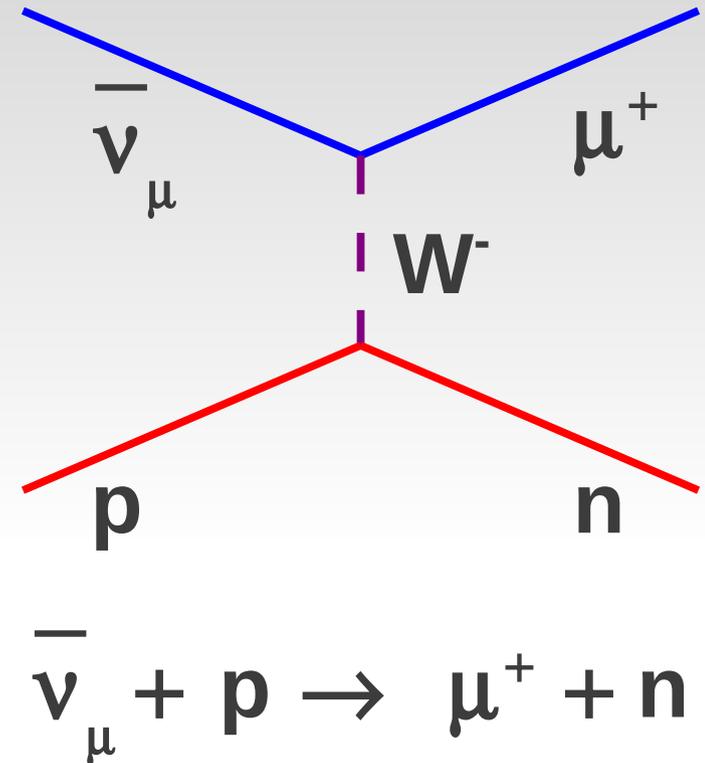


note: plot does not include MiniBooNE or SciBooNE data



MINERvA: CCQE

- Charged Current Quasi-Elastic (CCQE) scattering
- Neutron not always observed
- Vertex separation between neutron and muon
- Reconstruct neutrino energy using only muon kinematics



$$E_{\bar{\nu}_\mu} = \frac{2(m_p - \epsilon_B)E_\mu - ((m_p - \epsilon_B)^2 + m_\mu^2 - m_n^2)}{2((m_p - \epsilon_B)^2 - E_\mu + \sqrt{E_\mu^2 - m_\mu^2} \cos \theta_\mu)}$$

$$Q^2 = 2E_{\bar{\nu}_\mu}(E_\mu - p_\mu \cos \theta_\mu) - m_\mu^2$$

Binding energy
 $\epsilon_B = 30 \text{ MeV}$



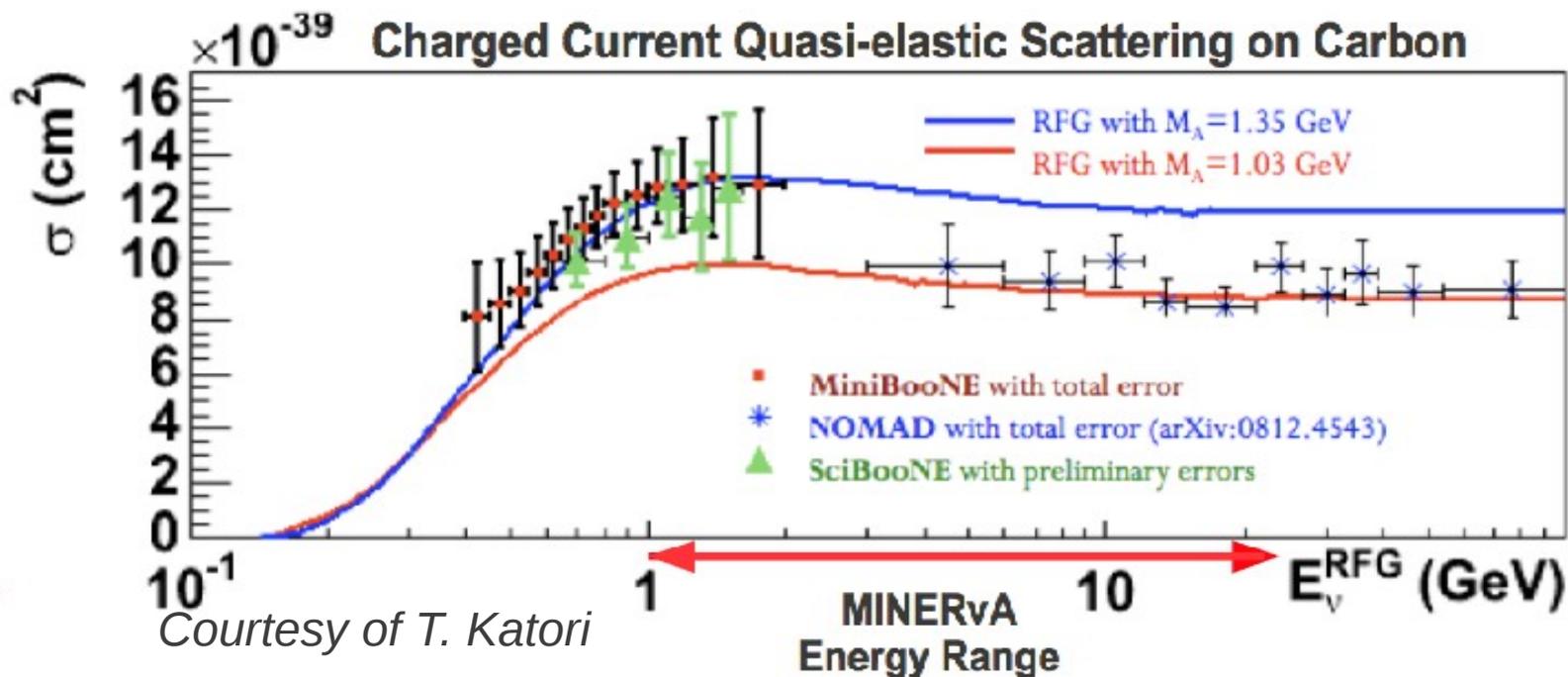
MINERvA: CCQE

- CCQE cross-section calculated using axial and vector form factors
 - Vector form factors have been measured using electron-nucleon scattering
 - Axial form factor (F_A) can be measured using neutrino-nucleon scattering
 - Dipole approximation →
 - Could take another form

$$F_A(Q^2) = \frac{F_A(0)}{\left(1 + \frac{Q^2}{M_A^2}\right)^2}$$

MINERvA: CCQE Motivation

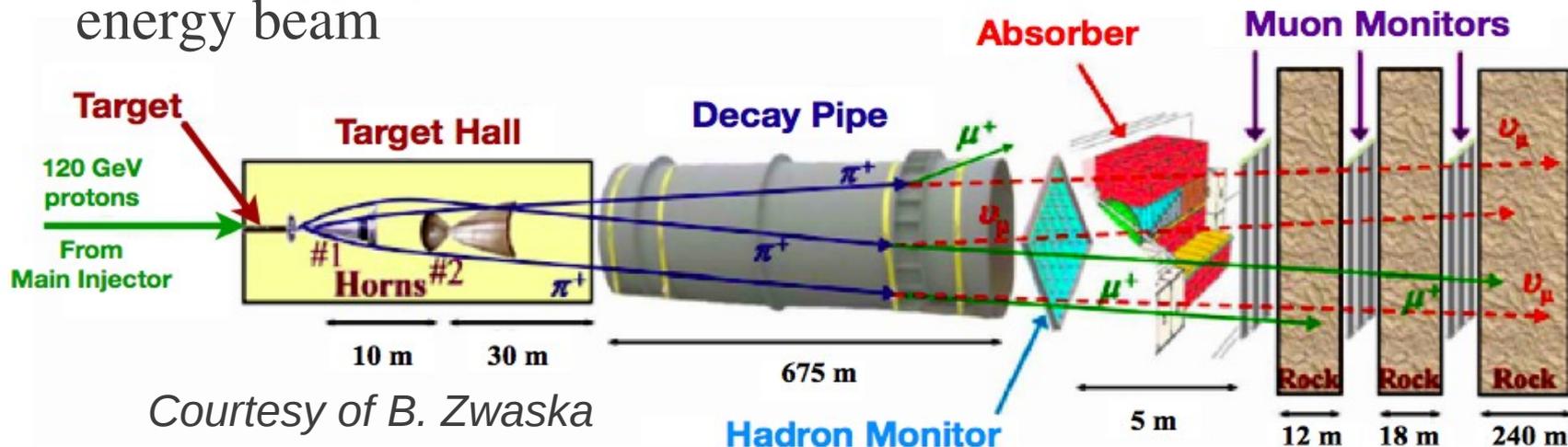
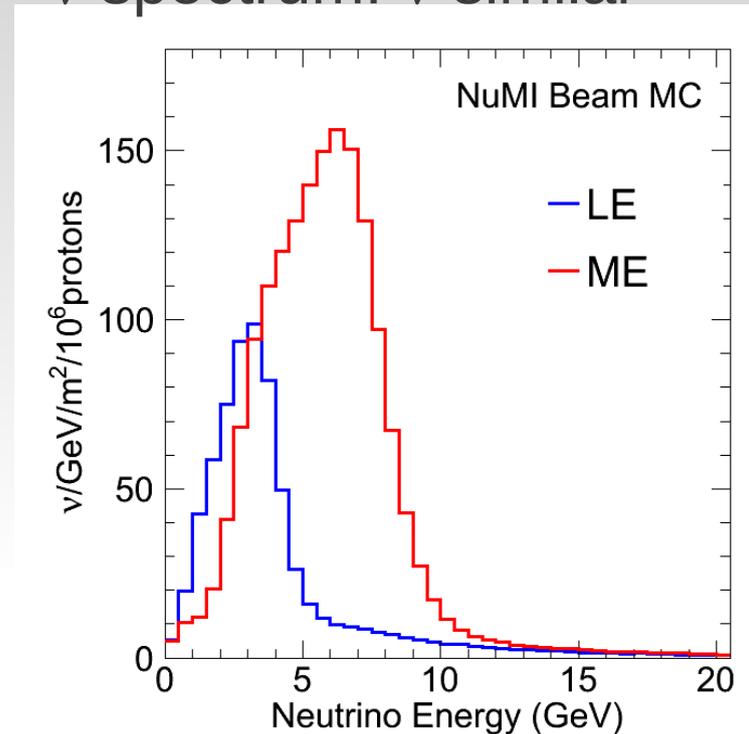
- CCQE: Common oscillation signal (T2K, MiniBooNE), flux standard candle
- Discrepancy between low and high energy CCQE cross-section measurements
 - We measure - interaction, nuclear effects, detector response
- MINERvA has capability of answering this question
 - Broad energy spectrum, multiple targets over range of A
 - Sensitive enough detector to look at different detector signatures



MINERvA: NuMI Beamline

- 120 GeV protons collide with carbon target
 - Resultant mesons (π/K) focused
 - Decay to neutrinos
- Reversible horn polarity - sign select mesons:
 - ν_μ and $\bar{\nu}_\mu$ beam capability
- MINERvA will run in low and medium energy beam

ν spectrum: $\bar{\nu}$ similar

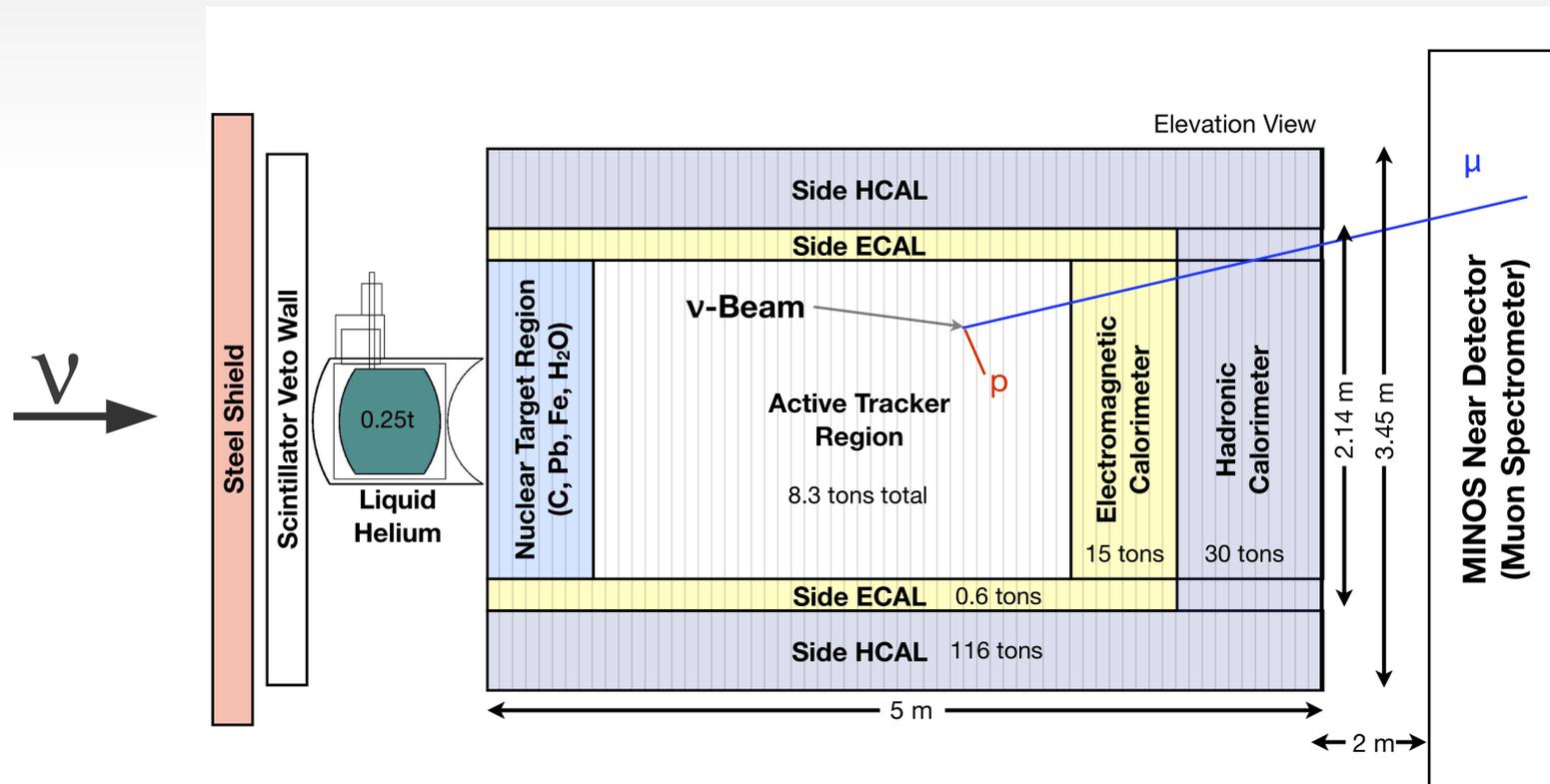


Courtesy of B. Zwaska

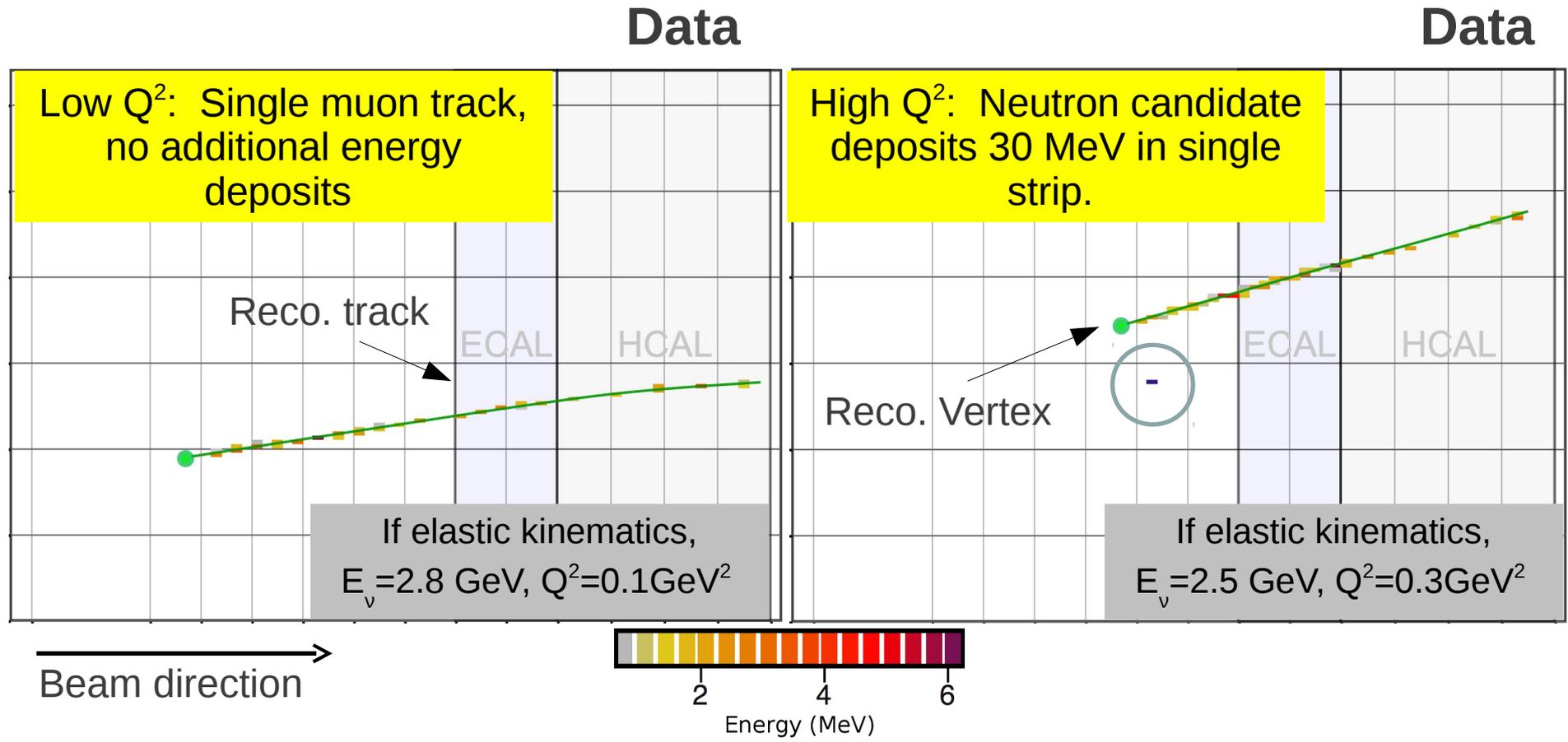


MINERvA: The Detector

- MINERvA: 120 planes, 200 tons, 32K channels
 - Multiple nuclear targets: He, C, CH, H₂O, Fe, Pb
- MINOS used as muon spectrometer
 - Magnetised – can determine muon charge

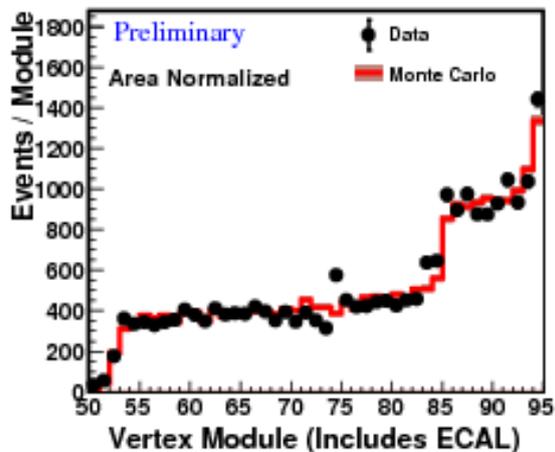
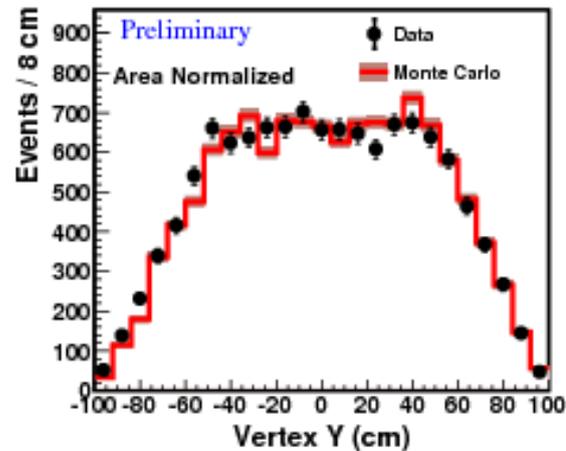
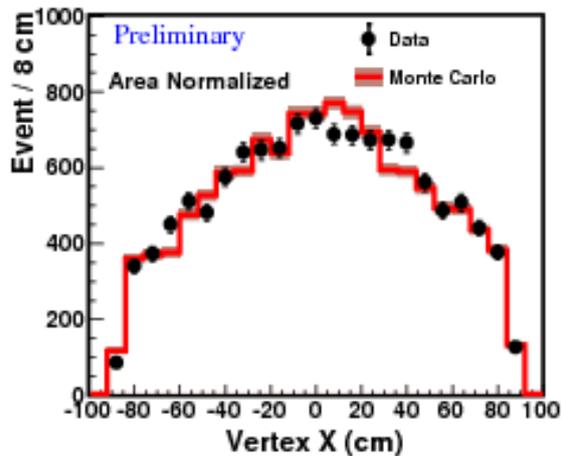


MINERvA: $\bar{\nu}_\mu$ CCQE Signature



MINERvA: CCQE Analysis

Vertex Distributions for CC events

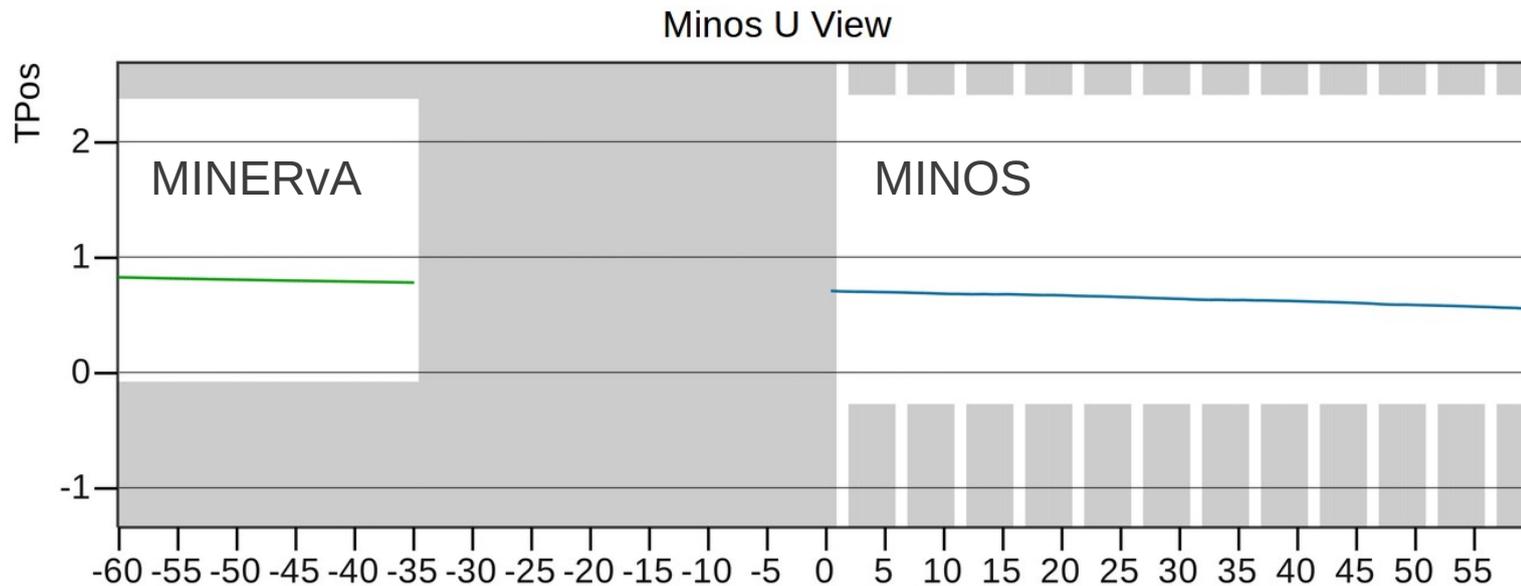
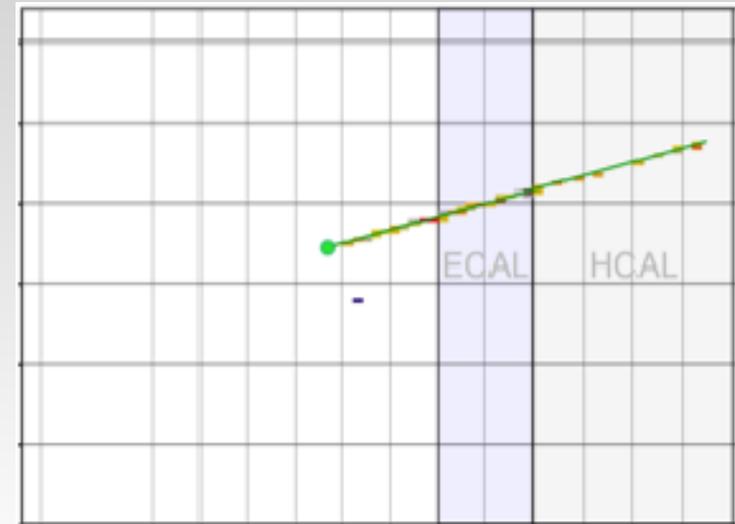


- Anti-neutrino analysis on partial detector era
 - 64 planes (~ half MINERvA detector)
 - 4×10^{19} protons on target (POT)
 - Current data set = 1.7×10^{20} POT
 - Monte Carlo: $M_A = 0.99 \text{ GeV}/c^2$
- Good data-to-MC agreement seen in vertex distributions



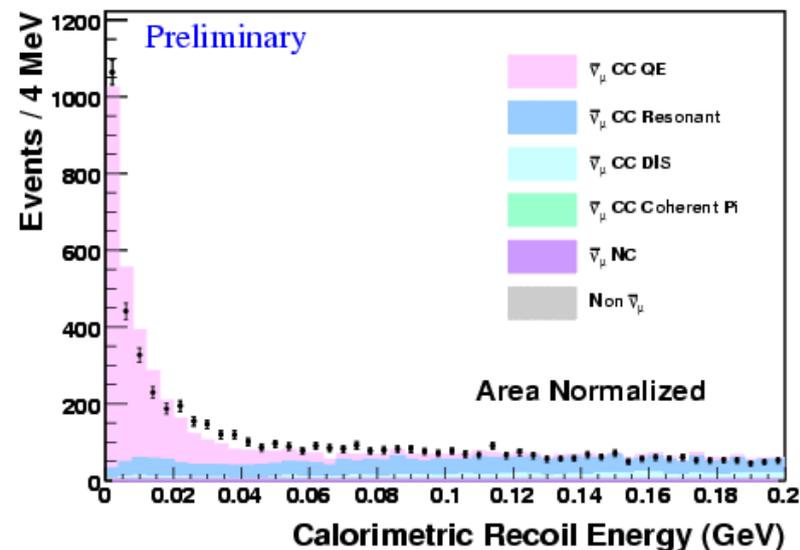
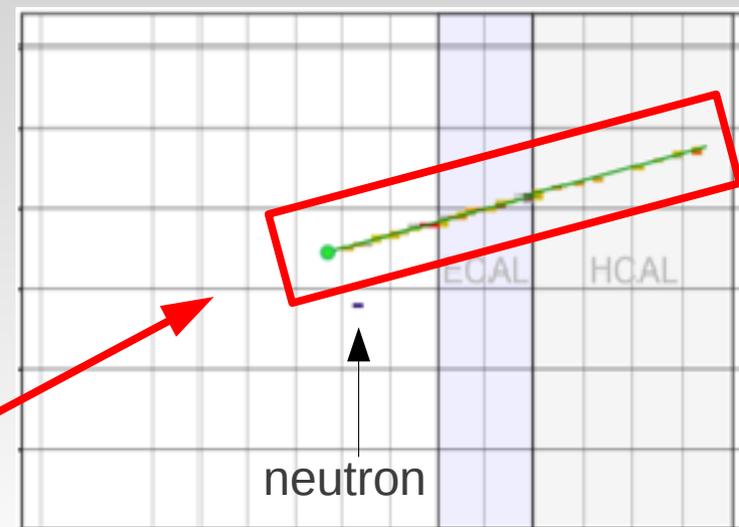
MINERvA: CCQE Analysis

- Event Selection
 - Event vertex in MINERvA fiducial volume (2.86 tons)
 - CH target
- Muon track enters MINOS detector
 - Muon charge selection



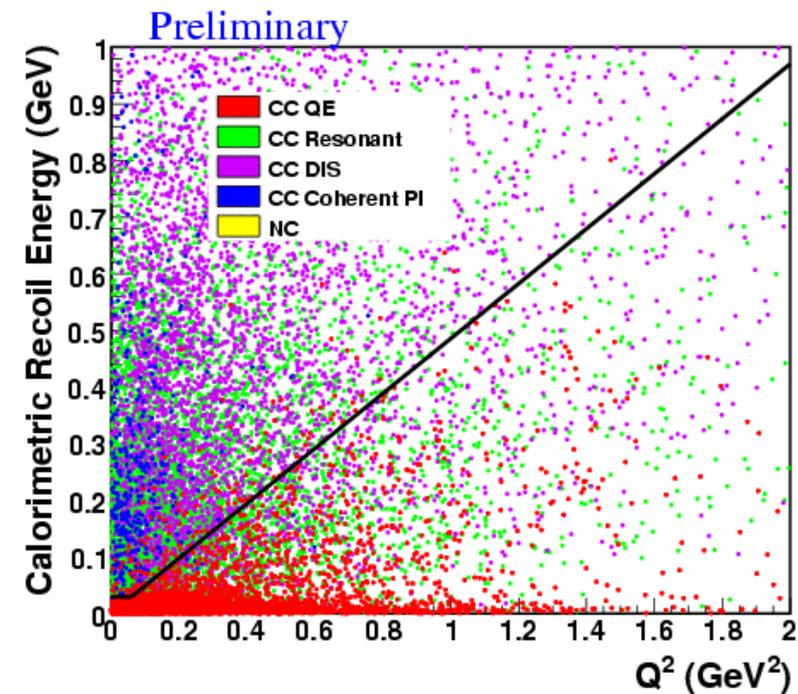
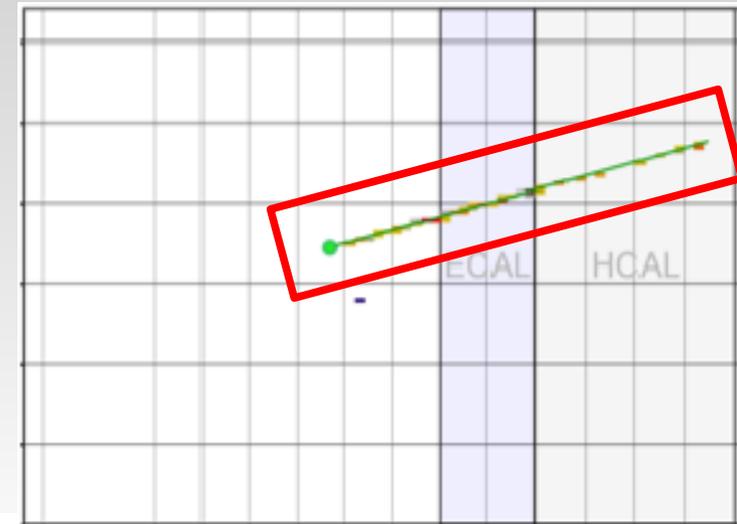
MINERvA: CCQE Analysis

- Event Selection
 - Event vertex in MINERvA fiducial volume (2.86 tons)
 - CH target
- Muon track enters MINOS detector
 - Muon charge selection
- Recoil energy cut
 - Sum all energy outside 5cm of track
 - QE sample at low recoil energy
- However high Q^2 CCQE events rejected
 - Introduce Q^2 dependent recoil cut
 - Scales with $Q^2/2m_p$



MINERvA: CCQE Analysis

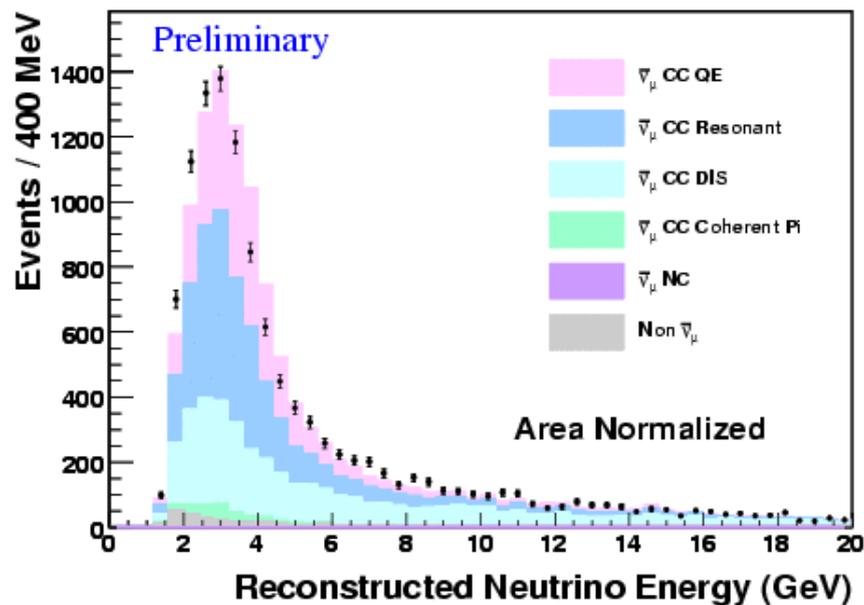
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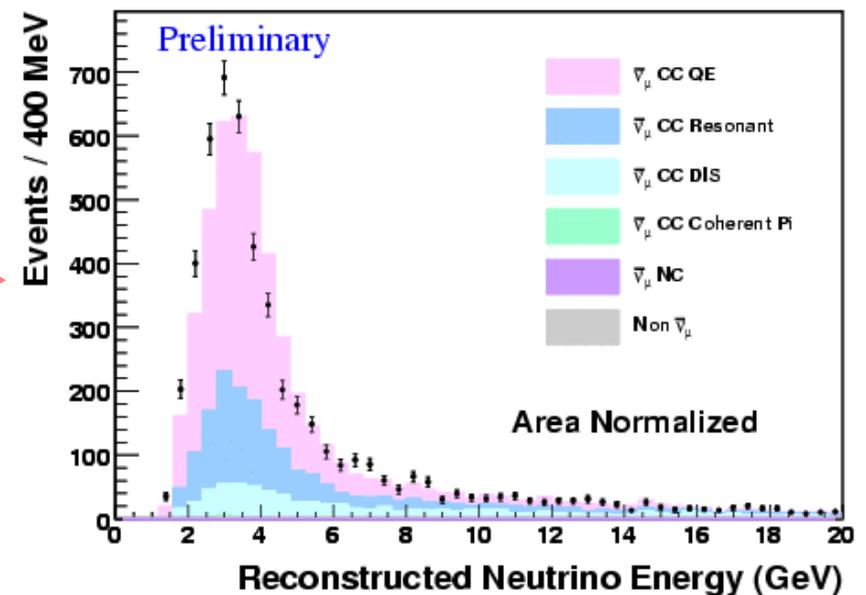
MINERvA: Distributions

- Area normalised plots, statistical errors only
- Recoil cut effectively selects CCQE events
- Fairly good shape agreement

Before Recoil Cut

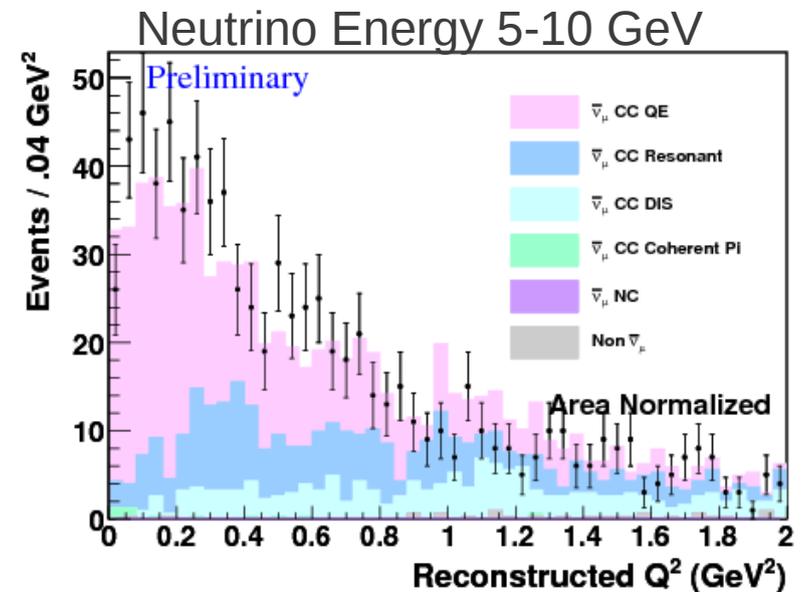
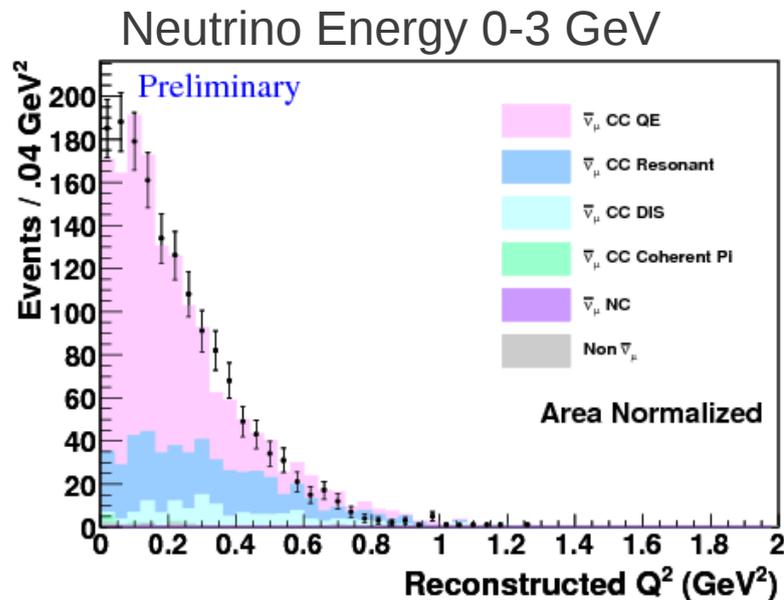
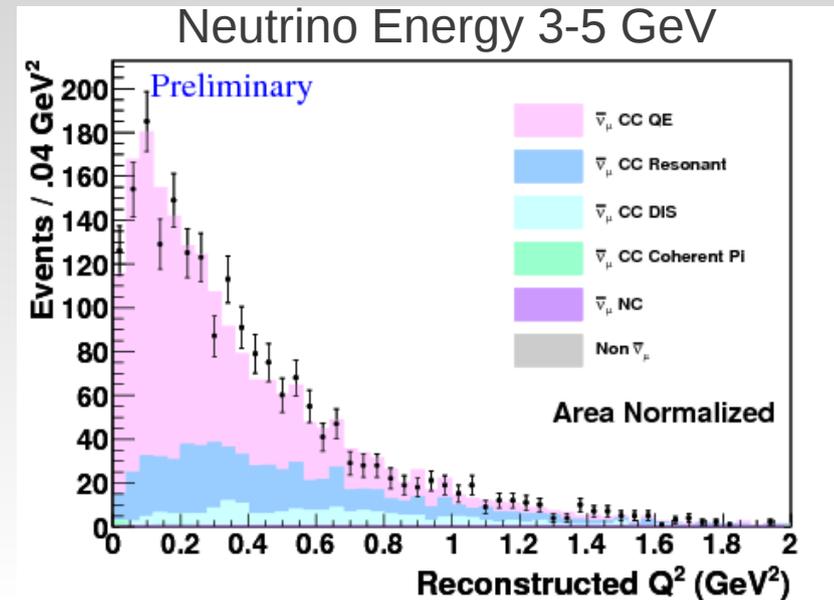


After Recoil Cut



MINERvA: Distributions

- Area normalised. Statistical errors only
- Broad Q^2 distribution, large background at high Q^2
- Good shape agreement for all energy ranges



Summary

- MINERvA has unique ability to answer numerous puzzles seen in current cross-section data
- Have shown that MINERvA can effectively select CCQE events
- Work ongoing on an increased data set with the goal of producing CCQE cross-section results soon...

Stay tuned!



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Back-up



MINERvA: Data Taking

